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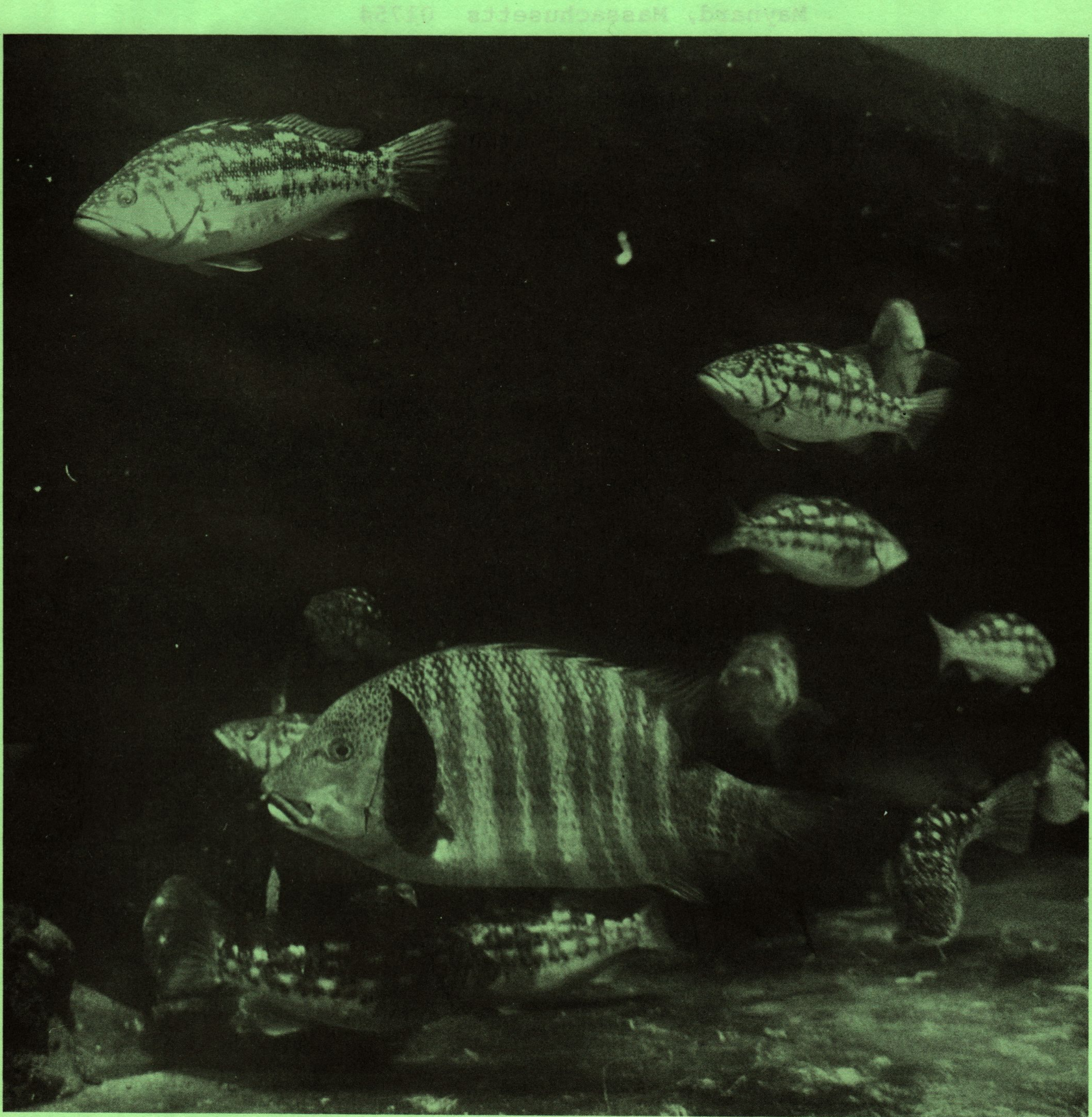

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RESOURCE
MANUAL

TAG

"TAGGING AND RECOVERY" METHOD FOR WILDLIFE POPULATION STUDY

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HUNTINGTON TWO COMPUTER PROJECT

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TAG

RESOURCE MANUAL

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I. BACKGROUND MATERIALS FOR *TAG* PROGRAM

Man needs knowledge about wildlife in order to ensure its continued existence. Our destruction of natural habitats in the search of energy and raw materials, as well as living space, has threatened the existence of many species.

Before we can do anything significant to aid or protect a particular species, we need to know certain things about the species and its environment. One thing in particular that we need to know about the species is the size of its population in a given area.

Determining the size of a wildlife population is hardly ever an easy job. It is easier to do with some populations than with others, and the task is simplified when the population inhabits an area with natural boundaries, since the location of all the members of the population can be clearly determined.

One such self-contained area is a small lake or farm pond. In such a pond it might be possible to count all of the individual fish of one species (e.g., bass) by some method such as draining the pond or removing all of the fish. Either of these methods would, however, drastically alter the ecology of the pond and threaten the existence of the bass we are trying to aid!

The problem of counting the fish in a farm pond requires some other solution. One solution lies in the use of *sampling* techniques and *statistical estimates*. Proper sampling and proper treatment of sampling results can provide us with a good estimate of the size of any wildlife population.

Tagging and Estimating

One method used to estimate the number of individuals in any area calls for taking a known number of individuals, marking them for later identification, and then setting them free in the area to be studied. At a later date, when complete mixing of the marked individuals with the rest of the population has occurred, a small sample is taken from the area and a comparison of the number of marked individuals with unmarked individuals is made in order to obtain an estimate of the total population size. Suppose, for example, that 1000 marked fish are released in a pond and that 50 fish are caught later, with 10 of these marked and 40 of them unmarked; then the entire population may be estimated to be 5000 fish. (*REASONING*: 1 fish of every 5 in the sample was marked; if 1000 marked fish were released and if, indeed, 1 fish of every 5 in the total population is marked as our sample indicates -- then there must be a total of 5000 fish in the pond.)

We must remember that sampling is always subject to error and that only careful planning will help us to keep this error small. Our sampling will be in error if we do not allow enough time to pass before sampling, in order to allow the marked fish to swim to all parts of the pond and to mix completely with the other fish. Another point to consider is that some areas of the pond may not provide as much cover or food for the fish, so that fish will seldom swim into those areas, and those areas will remain "under-represented" in terms of population.

By choosing a number of sites for sampling and allowing an adequate amount of time for migration to these sites, we can get better estimates of population size.

Something else that you will want to consider is the number of tagged fish required to provide a good estimate of the total population. Obviously, the more tagged fish released, the greater the change in the ecology of the pond as well as in the cost of the study. *THIS MEANS THAT YOU WILL WANT TO DETERMINE THE LEAST NUMBER OF TAGGED FISH REQUIRED FOR A GOOD ESTIMATE OF THE TOTAL NUMBER OF FISH IN THE POND.*

II. SUGGESTED PROJECTS

A. Take a field trip to a local farm pond (*TAG* simulates a 5-acre pond). On this trip, teams of students could be assigned different areas of study such as the following:

   1) feasibility of counting the total fish population by draining the pond or removing all the fish;

   2) environmental influences on the pond ecology such as pollutants draining into the pond; leaching from rich mineral ore deposits in the area; immigration or introduction of new aquatic life species, both plant and animal (this may require several student teams);

   3) pond shape and depth as a help or hindrance to actual diffusion of the fish being studied; also, a study of the best sampling site.

B. Take a field trip to a fish hatchery for the purpose of learning about fish-tagging methods and problems, different sampling techniques and the problems encountered in introducing fish from a hatchery into a new site such as the pond simulated in *TAG*.

C. Organize a group of students to make a study of the living environments, migrating habits, age, and health of certain species, as well as the problems encountered and results obtained by other groups or agencies in trying to sample or otherwise study these species. Such species could include the salmon, western elk, fox, rabbit, starling, some water fowl, or various insects.

D. Take a field trip to visit the offices of the fish and game commission to study, among other things, the role population counting plays in establishing the dates of the hunting and fishing seasons, and the duration of the seasons, as well as other control measures.

III. FURTHER INSTRUCTIONAL USES FOR THE PROGRAM

A. As with most simulation programs, a good supplementary exercise for students would be to examine the model which underlies the program to determine what changes or extensions could be made. Comparisons may be made between results obtained with the present model and those obtained with the new model.

B. The constants used in the present model can be changed easily (see Section IV. G for details). Experimentation with other values could be carried out, and the results compared with those obtained using the original values.

C. In addition to its obvious use in a biology classroom, *TAG* can be used by the mathematics teacher to introduce his students to the concept of proportion and to provide the students with practice in solving realistic proportion problems. (These exercises might also be used to provide students with experience in constructing a graph from a data sheet.) The more capable math students might wish to study in detail the equations given in Section IV of this *RESOURCE MANUAL* entitled, "DESCRIPTION OF THE MODEL USED."

D. The advanced student with a knowledge of computer programming could develop a more sophisticated model which not only would have a larger pond with more fish, but also a larger number of sites and a greater variation in site characteristics. Site characteristics could reflect accumulated data concerning the effects of pollution.*

E. Project work -- see Section VI of this manual.

---

*See the program *POLUT* for possible model of pollution effect.

IV. DESCRIPTION OF THE MODEL USED

A. Source of the Model

The model which is used in the *TAG* computer program is based on data from the New York State Conservation Department and Cornell University's Department of Conservation, and represents their experience with work of this kind.

B. Variables

The following variables are used in the *TAG* program. The numbers in parentheses are the values presently assigned to each variable. These variables can be altered according to the directions given in Part G of this Section.

Variable	Meaning
A	Area of the pond in square meters
A1	Area of diffusion of tagged fish
B	Bell-shaped randomizer
C	Probability of a tagged fish surviving 1 day (0.998)
C1	Probability of catching a tagged fish after its arrival at sampling location
D	Diffusion constant
E	Day of last sample (initially zero)
M	Number of tagged fish in sample Z
N	Total number of fish sampled in sample Z
P	Population of untagged fish in pond (424)
P1	Number of tagged fish placed in pond
P3	Actual number of tagged fish

Q	Response holder
R	Radius of pond in meters (75)
R1	Radius to sample site from center of diffusion
T	Day number
S	Density of tagged fish at site X, Y
X	X-coordinate of sampling site
Y	Y-coordinate of sampling site
Z	Sample number
Z9	Density of population that has reached edge of pond during time T.

C. Calculation of Diffusion through Pond

The density of tagged fish at any site is a function of the radius of that site from the center of diffusion (R1) and the length of time diffusion has been going on (T) as well as the number of tagged fish surviving at time T (P3).

1) Density of tagged fish

$$S = Z9 + \frac{\{\exp[-(R1-2.5)^2/(D*T)] - \exp[-(R1+2.5)^2/(D*T)]\} *P3}{3.14 * [(R1+2.5)^2 - (R1-2.5)^2]}$$

2) Population of tagged fish

$$P3 = C^T * P1$$

D. Calculated Probability of Catching Tagged Fish

The program checks first to determine if the tagged fish could have arrived at the sampling station. If not, the probability is set to zero. If the fish have arrived, the following formula is used:

$$C1 = \frac{S}{(S + P/A)}$$

E. Calculated Number of Tagged Fish Caught

The number of tagged fish caught is calculated by the following formula:

$$M = N * C1 + B * \sqrt{(C1 - C1^2) * N}$$

where $B * \sqrt{(C1 - C1^2) * N}$ is a measure of randomness.

The number of tagged fish actually used in the program is this value of M converted to an integer value by rounding up (i.e., by adding 0.5 and then ignoring the fractional part).

NOTE: Symbol (*) denotes multiplication.

F. Assumptions under Which the Model Operates

1) It is assumed that after each fish is caught and examined, it is returned to the pond.

2) The farm pond is essentially circular and has a total area of approximately 17,660 square meters (about 5 acres).

3) The untagged population of fish in the farm pond remains constant at 424. To alter this number for different class groups, see Section G below.

4) Introduction of tagged fish causes no great disturbance in the ecology of the farm pond. (This might not be true if large numbers of tagged fish were introduced.)

5) The small mortality rate (low death rate) of the tagged fish has a small effect on their rate of diffusion.

G. Altering the Model

1) Certain parameters used in the *TAG* model are quite easy to change. These are listed below:

Variable	Meaning
C	Probability of a tagged fish surviving 1 day (where 1 = 100%)

D	Diffusion constant (a larger D will cause faster diffusion of tagged fish)
P	Population of untagged fish in pond
R	Radius of pond in meters

The values for these variables are stored in a data statement, line 230 of the program, in the following order:

P, R, E, D, C

Currently, this data statement reads as follows:

```
230  DATA   424,    75,    0,    500,    .998
             ↑      ↑      ↑      ↑        ↑
             P      R      E      D        C
```

In order to change one of the values, line 230 in the program must be re-typed, with the new value for a variable entered in the appropriate place. For example, to change the diffusion constant for the fish from 500 to 210 and the pond size from 75-meter radius to 100-meter radius, enter the following line after the program is called, but before the computer is instructed to run:

```
230  DATA   424,     100,       0,    210,       .998
                      ↑                ↑
               (R is changed) (D is changed)
```

Notice that the values for the unchanged variables are typed in exactly as they were before. The computer will now use the new values which have been entered when it is instructed to run the program.

2) Elimination of computer calculation for total population size. Line 640 currently reads

```
640 PRINT
```

Re-type this line as

```
640 STOP
```

This modification will eliminate both the calculation and evaluation features from the program.

3) Decreasing the computer storage required by *TAG*.

a) In order to accommodate users who are limited by the memory available on their machines, the paper-tape copy of *TAG* is arranged to permit the loading of the program without REM statements and student instructions. All REM statements are included in the first part of the tape and are separated from the main body of the program by a section of tape with just leader holes punched. In order to load the reduced-size program, it is necessary only to start the program tape near the middle of the second section of leader holes.

b) Elimination of calculation and evaluation sections. Depending on the particular version of BASIC being used, this can be done by typing

```
DELETE 645, 825   or  DELETE 645-845
```

after the tape has been loaded.

With BASIC versions lacking the DELETE command, these lines can be deleted by typing the appropriate line number and then hitting the return key for each line.

The combined deletions described in (a) and (b) above decrease the length of *TAG* from 166 lines (about 3800 characters) to 86 lines (about 2200 characters).

4) Changing maximum number of samples allowed

a) Line 215 currently reads:

```
215  DIMN(20), M(20)
```

Replace 20 with the maximum sample number.

b) Line 420 currently reads:

```
420  IF Z = 21 THEN 585
```

Replace 21 with maximum number plus one.

c) Change text in lines 205, 585.

Machines with limited memory may not accept larger maximum number of samples.

V. *TAG* PROGRAM LISTING

```
100 REM - TAG: A SURVEY OF BASS POPULATION IN A SIMULATED FARM
105 REM POND USING TAGGING AND RECOVERY.
110 REM COPYRIGHT 1972,1973 -STATE UNIVERSITY OF NEW YORK
115 REM MODEL AND PROGRAM DESIGN: J. FRIEDLAND
120 REM LATEST REVISION: 7/20/73
125 REM P=POP. OF BASS;P1=POP. OF TAGGED BASS
130 REM R=RADIUS OF POND;R1=RADIUS OF SAMPLE SITE
135 REM A=AREA OF POND;T=DAY NUMBER
140 REM D=DIFFUSION FACTOR;C=CHANCE OF TAGGED BASS SURVIVAL/DAY
145 REM C1=CHANCE OF CATCHING A TAGGED BASS VS. AN UNTAGGED BASS
150 PRINT"DO YOU REQUIRE INSTRUCTIONS (1=YES, 0=NO)";
155 INPUTQ
160 IFQ=0THEN210
165 IFQ<>1THEN155
170 PRINT
175 PRINT
180 PRINT"      THE OBJECT IS TO DETERMINE THE NUMBER OF BASS"
185 PRINT"IN THE POND SHOWN IN YOUR LAB GUIDE. THE TECHNIQUE"
190 PRINT"CALLS ON YOU TO INTRODUCE TAGGED FISH INTO THE POND"
195 PRINT"AND, AT SOME LATER DATE, SAMPLE THE POND'S FISH"
200 PRINT"TO DETERMINE THE PERCENTAGE OF FISH THAT ARE TAGGED."
205 PRINT"      YOU ARE ALLOWED ONLY 20 SAMPLES, SO CHOOSE CAREFULLY."
210 PRINT
215 DIMN(20),M(20)
220 LETZ=0
225 READP,R,E,D,C
230 DATA424,75,0,500,.998
235 RANDOMIZE
240 LETA=3.14*R↑2
245 PRINT"HOW MANY TAGGED BASS DO YOU WANT FROM THE HATCHERY";
250 INPUTP1
255 IFP1<=400THEN270
260 PRINT"SORRY, MAXIMUM NUMBER OF FISH AVAILABLE IS 400"
265 GOTO245
270 PRINT
275 PRINT"HOW MANY DAYS, AFTER RELEASE OF THE BASS"
280 PRINT"FROM THE CENTER OF THE POND, DO YOU WANT TO SAMPLE";
285 INPUTT
290 IFT>ETHEN310
295 PRINT
300 PRINT"DAY ";T;" HAS PASSED"
305 GOTO275
310 PRINT
315 LETP3=C↑T*P1
320 LETZ9=EXP(-(R↑2/(D*T)))*P3/A
325 PRINT"AT WHAT SITE DO YOU WANT TO SAMPLE FIRST";
330 IFE<>0THEN350
335 PRINT
340 PRINT"(REFER TO MAP IN STUDENT MANUAL FOR X AND Y COORDINATES."
345 PRINT"ENTER AS X,Y)";
350 INPUTX,Y
```

```
355 LETR1=SQR(X↑2+Y↑2)
360 IFR1>.1THEN370
365 LETR1=.1
370 IFR1<=RTHEN390
375 PRINT
380 PRINT"SAMPLE SITE BEYOND SHORES OF POND"
385 GOTO340
390 LETS=EXP(-(R1-2.5)↑2/(D*T))-EXP(-(R1+2.5)↑2/(D*T))
395 LETS=(S*P3)/(3.14*((R1+2.5)↑2-(R1-2.5)↑2))+Z9
400 LETC1=S/(S+P/A)
405 IFC1>1E-19THEN415
410 LETC1=0
415 LETZ=Z+1
420 IFZ=21THEN585
425 PRINT"HOW MANY FISH";
430 INPUTN(Z)
435 LETN(Z)=INT(N(Z))
440 IFN(Z)<=400THEN455
445 LETN(Z)=INT(200*RND(0)+200)
450 PRINT"IT WAS POSSIBLE TO CATCH ONLY ";N(Z);" FISH."
455 LETB=COS(6.283*RND(0))*SQR(-2*LOG(RND(0)))
460 LETM(Z)=INT(C1*N(Z)+B*SQR((C1-C1↑2)*N(Z))+.5)
465 IFM(Z)*(N(Z)-M(Z))<0THEN455
470 PRINT" SAMPLE: ";Z
475 PRINT"STATION: ";X;",";Y;"     DAY: ";T
480 PRINT" TAGGED: ";M(Z);"    UNTAGGED: ";N(Z)-M(Z)
485 PRINT
490 PRINT
495 PRINT"ANOTHER SAMPLE ON DAY ";T;
500 IFZ>1THEN510
505 PRINT" (1=YES, 0=NO)";
510 INPUTQ
515 PRINT
520 IFQ<>1THEN535
525 PRINT"SITE COORDINATES";
530 GOTO350
535 IFQ<>0THEN505
540 PRINT"DO YOU WANT TO SAMPLE ON ANOTHER DAY";
545 IFE<>0THEN555
550 PRINT" (1=YES, 0=NO)";
555 INPUTQ
560 IFQ=0THEN590
565 IFQ<>1THEN550
570 PRINT"WHAT DAY NUMBER";
575 LETE=T
580 GOTO285
585 PRINT"YOU MAY TAKE A MAXIMUM OF 20 SAMPLES"
590 PRINT
595 PRINT
```

```
600 PRINT"IF YOU HAVE SELECTED YOUR SAMPLES CAREFULLY"
605 PRINT"YOU SHOULD BE ABLE TO DETERMINE THE TOTAL"
610 PRINT"BASS POPULATION OF THE POND."
615 PRINT
620 PRINT"  YOU CAN USE THE FORMULA:"
625 PRINT"              (TOTAL TAGGED FISH IN POND) X (SAMPLE SIZE)"
630 PRINT"  TOTAL POP.= ------------------------------------------"
635 PRINT"                (NUMBER OF TAGGED FISH RECOVERED AT SITE)"
640 PRINT
645 PRINT"DO YOU WISH TO DO THE CALCULATIONS YOURSELF(1=YES, 0=NO)";
650 INPUTQ
655 IFQ<>0THEN760
660 PRINT
665 PRINT"WHICH SAMPLE DO YOU WISH TO EVALUATE FIRST";
670 PRINT" (SAMPLE NUMBER)";
675 INPUTQ
680 IFQ>ZTHEN670
685 LETQ=INT(Q)
690 PRINT
695 PRINT"          ";P1;"  X  ";N(Q)
700 LETW=0
705 IFM(Q)=0THEN715
710 LETW=INT(P1*N(Q)/M(Q))
715 PRINT"          --------------- = ";W
720 PRINT"               ";M(Q)
725 PRINT
730 PRINT
735 PRINT"ANOTHER CALCULATION (1=YES,0=NO)";
740 INPUTQ
745 PRINT
750 IFQ=1THEN670
755 IFQ<>0THEN735
760 PRINT
765 PRINT"ENTER YOUR ESTIMATE OF THE UNTAGGED BASS POPULATION";
770 INPUTQ
775 PRINT
780 IFABS((Q-P)/P)>.1THEN795
785 PRINT"YOUR ESTIMATE IS GOOD.  CONGRATULATIONS."
790 STOP
795 IFABS(P-Q)/P<=.25THEN820
800 PRINT"YOUR ESTIMATE IS NOT WITHIN 25 PERCENT"
805 PRINT"OF THE ACTUAL POPULATION."
810 PRINT"EXAMINE YOUR SAMPLING STATEGY AND TRY AGAIN."
815 STOP
820 PRINT"YOUR ESTIMATE IS CLOSE, BUT NOT WITHIN 10 PERCENT"
825 GOTO805
830 END

READY
```

VI. ADDITIONAL EXERCISES USING *TAG*

These projects have been included for the student interested in further project work.

PROJECT 1 -- Minimizing tagged population

As you know, an ecologist will always sample a population in such a way as to minimize the damage to the environment and the species being studied. Let's return to our farm pond example. There is only a certain amount of space and a certain amount of food available to the fish already present. Introducing tagged fish is certain to upset the natural balance. One solution might be to trap fish from the pond, tag them and then re-release them back into the pond.

Another solution to the problem would be to use as few fish as possible to arrive at your answer. The objective of this project is to determine the smallest number of tagged fish that will give a reliable answer at least 50% of the time.

Solving this problem will require many trials. To start you might use 100 fish for the investigation and, if that proves satisfactory, use a smaller number. Keep reducing the number of tagged fish until you get an acceptable estimate only about 50% of the time.

In your report be sure to include the strategy you used for estimating the total population.

PROJECT 2 -- Study of diffusion within a pond

In the *STUDENT MANUAL*, it was noted that the fish were released in the center of the pond. As time goes on, the fish diffuse away from the center of the pond until they are randomly mixed with the untagged population. How does this diffusion take place? A partial answer to the question can be found by sampling at the same location each day and then graphing the results, with the per cent of tagged fish in the sample on the vertical axis and days on the horizontal axis.

Try this technique for several locations in the pond. Choose as one of these location sites (0,0) -- the place where the fish were placed at the beginning of the diffusion.

PROJECT 3 -- Investigation of a larger pond

To enlarge the pond under investigation, it is necessary to alter the program *TAG*. After the program has been loaded or called and before you type "RUN", you must re-type line 230.

Currently, line 230 reads:

```
230 DATA 424,75,0,500,.998
```

The second number in the line describes the radius of the pond. You can enlarge the pond by typing a larger number in its place. For example, if you wanted to enlarge the pond to a radius of 100 meters, you would type

```
230 DATA 424,100,0,500,.998
```

Notice that everything is the same except for the second number.

After this change has been made, you are ready to begin your investigation. Here are some questions you might try to answer:

a) Does doubling the size of the pond (to 150 meters radius) double the amount of time necessary for diffusion?

b) Does doubling the size of the pond affect the accuracy of your strategy for determining total bass population?

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